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Channeling STIM analysis of radiation damage in single crystal diamond membrane

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ABSTRACT

The use of focused ion beam transmission channeling patterns to monitor the damage creation process in thin diamond single crystal membrane is described. A 0.8 MeV proton beam from the Ruđer Bošković Institute nuclear microprobe was used to perform Channeling Scanning Transmission Ion Microscopy (CSTIM) measurements. CSTIM was used instead of RBS channeling because of (several orders of magnitude) lower damage done to the sample during the measurements. Damage was introduced in selected areas by 15 MeV carbon beam in range of fluences $3{\cdot}10^{15}$–$2{\cdot}10^{17}$ ions/cm^2. Contrary to Ion Beam Induced Charge (IBIC), CSTIM is shown to be sensitive to the large fluences of ion beam radiation. Complementary studies of both IBIC and CSTIM are presented to show that very high fluence range can be covered by these two microprobe techniques, providing much wider information about the diamond radiation hardness. In addition micro Raman measurements were performed and the height of the GR 1 peak was correlated to the ion beam fluence.

1. Introduction

The important advantage of the microprobe irradiation of materials to study processes of defect creation is its capability to damage only a small fragment of an irradiated material or device. This is of particular importance for valuable materials, such as diamond, that are difficult to study by bulk irradiation. In the case of diamond, influence of radiation damage has been studied previously using microprobe technique Ion Beam Induced Charge (IBIC) [1] that provides data about degradation of the charge transport properties. Recently, it has been have shown that thin diamond membranes (less than 10 µm thick) are much more suitable for such studies as effects of space charge (polarisation) are minimized [2,3]. However, due to the almost complete degradation of electronic properties when fluence reaches a certain value, other characterization techniques should be used. In an attempt to monitor effects of diamond membrane irradiated by high ion beam fluence, we have explored the use of ion channeling that seems to be more applicable since it is more sensitive to significant degradation of the crystal lattice structure. Furthermore a channeling rate that corresponds to the radiation damage can be correlated quantitatively to the density of created defects. In order to minimize effects of irradiation during the measurements, Channeling Scanning Transmission Ion Microscopy (CSTIM) is used instead of the more conventional Rutherford Backscattering Spectrometry channeling (RBS channeling). In CSTIM almost all ions that pass trough the sample are detected, whereas in RBS channeling only a very small fraction of the ions is backscattered. Therefore damage done to the sample during the measurement is several orders of magnitude lower. Additionally, since high intensity beam is not needed for CSTIM, better focusing of the ion beam is possible and therefore spatial resolution is better. The CSTIM technique has been frequently used to study defects in crystals, starting with silicon [4–7], and then other materials like SiGe [8] or HgCdTe [9] and others.

This technique is supposed to be sensitive to high damage fluences, whereas IBIC studies are sensitive to significantly lower damage fluences. Hence, complementary studies with both IBIC and CSTIM can cover rather large fluence range, providing more comprehensive information about the diamond radiation hardness. Since both are low current techniques, additional damage to the sample during the testing is minimal.

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